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Genetic parameters for body weight from birth to calving and associations between weights with test-day, health, and female fertility traits

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ABSTRACT

A data set including 57,868 records for calf birth weight (CABW) and 9,462 records for weight at first insemination (IBW) were used for the estimation of direct and maternal genetic effects in Holstein Friesian dairy cattle. Furthermore, CABW and IBW were correlated with test-day production records and health traits in first-lactation cows, and with nonreturn rates in heifers. Health traits considered overall disease categories from the International Committee for Animal Recording diagnosis key, including the general disease status, diarrhea, respiratory diseases, mastitis, claw disorders, female fertility disorders, and metabolic disorders. For single trait measurements of CABW and IBW, animal models with maternal genetic effects were applied. The direct heritability was 0.47 for CABW and 0.20 for IBW, and the direct genetic correlation between CABW and IBW was 0.31. A moderate maternal heritability (0.19) was identified for CABW, but the maternal genetic effect was close to zero for IBW. The correlation between direct and maternal genetic effects was antagonistic for CABW (−0.39) and for IBW (−0.24). In bivariate animal models, only weak genetic and phenotypic correlations were identified between CABW and IBW with either test-day production or health traits in early lactation. Apart from metabolic disorders, there was a general tendency for increasing disease susceptibilities with increasing CABW. The genetic correlation between IBW and nonreturn rates in heifers after 56 d and after 90 d was slightly positive (0.18), but close to zero when correlating nonreturn rates with CABW. For the longitudinal BW structure from birth to the age of 24 mo, random regression models with the time-dependent covariate "age in months" were applied. Evaluation criteria (Bayesian information criterion and residual variances) suggested Legendre polynomials of order 3 to modeling the longitudinal body weight (BW) structure. Direct heritabilities around birth and insemination dates were slightly larger than estimates for CABW and IBW from the single trait models, but maternal heritabilities were exactly the same from both models. Genetic correlations between BW were close to 1 for neighboring age classes, but decreased with increasing time spans. The genetic correlation between BW at d 0 (birth date) and at 24 mo was even negative (−0.20). Random regression model estimates confirmed the antagonistic relationship between direct and maternal genetic effects, especially during calfhood. This study based on a large data set in dairy cattle confirmed genetic parameters and (co)variance components for BW as identified in beef cattle populations. However, BW records from an early stage of life were inappropriate early predictors for dairy cow health and productivity.
Key words: body weight, health and fertility trait, genetic parameter

INTRODUCTION

Body weight of dairy cattle is a novel trait of increasing economic importance, because BW change indicates maintenance requirements of lactating cows and growing heifers, determines the carcass values of cows, and is associated with weight development in offspring (Byrne et al., 2016). Energy balance modeling via BW changes is also important from a breeding perspective, especially during the early lactation stage directly after calving (Coffey et al., 2002). The negative energy balance impairs health and fertility (Collard et al., 2000), as well as productivity in the ongoing and later lactations of milking cows (Berry et al., 2003a). Compared with other components determining energy balance (e.g., DMI, methane emissions, or NE_M), BW is quite easy to measure under practical on-farm conditions.

Direct heritabilities for BW from different age points reported in literature were in a moderate to high range (Table 1), indicating the potential for genetic improvements. Also moderate to high genetic correlations between BW of milking cows with DMI and energy balance (Veerkamp et al., 2000) suggest BW recording

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and utilization for correlated selection response. However, for production and reproduction traits, genetic correlations with BW were low and varied across studies (Table 1). For calf birth weight (**CABW**), direct heritabilities were significantly larger compared with maternal heritabilities (Everett and Magee, 1965; Johanson et al., 2011). Moderate to high positive genetic correlations between CABW with dystocia, perinatal mortality, and gestation length were reported by Johanson et al. (2011). Availability of producer diagnosis keys for cow health traits according to International Committee for Animal Recording (**ICAR**) guidelines (Stock et al., 2013), and reflecting the disease categories of claw disorders, mastitis, metabolic disorders, and female fertility disorders, allow further association studies with BW measurements. However, to our knowledge, detailed genetic analyses in this regard are lacking.

Body weight recording allows a longitudinal data structure measured at different time points, including birth weight, weaning weight, cow calving weight, or BW from different lactation stages (Lamb and Barker, 1975; Coffey et al., 2006). Generally, genetic correlations for weight measurements from time points in close distance were quite large [e.g., 0.79 between birth weight and weaning weight (Coffey et al., 2006)], and between BW in wk 1 and 15 of lactation (Veerkamp and Thompson, 1999). In contrast, genetic correlations between distant time measurements were quite small [e.g., 0.14 between BW from d 50 to 900; Brotherstone et al. (2007)]. For genetic analyses of longitudinal weight data, repeatability models (e.g., Abdallah and McDaniel, 2000), multiple trait models (e.g., Veerkamp and Thompson, 1999), or the random regression model (**RRM**, e.g., Coffey et al., 2006) can be applied. Repeatability model applications assume identical genetic and environmental variances across the given time period. An alternative is to consider repeated weight measurements from different periods as separate traits, being the data basis for multiple trait model applications (Veerkamp and Thompson, 1999). Multiple trait models allow consideration of altering additive-genetic and residual variances, with positive effects on the accuracy of genetic evaluations (Thompson and Meyer, 1986). However, in the case of a large number of traits, the multiple-trait model might be over-parameterized (Veerkamp and Thompson, 1999). In RRM, alterations of genetic parameters and breeding values over the recording trajectory can be estimated based on a limited number of random regression coefficients.

Table 1. Overview of heritabilities for BW traits and their genetic correlations with production, fertility, and health traits in Holstein cows

	Heritability		Genetic correlation		
Trait	Direct	Maternal	Trait	Value	Reference
Birth weight	0.22	0.04	Gestation length	0.57	Everett and Magee, 1965
Birth to d 36 weight	0.58				Brotherstone et al., 2007
Birth weight	0.26	0.08	Dystocia	0.73	Johanson et al., 2011
			Perinatal mortality	0.57	
			Gestation length	0.52	
BW[1]	0.60		Milk yield	−0.03	Berry et al., 2003a
			Protein yield	0.03	
			Fat yield	−0.01	
			Interval to first service	−0.25	
			Pregnant to first service	−0.22	
			First service to conception interval	0.37	
			Number of services	0.15	
BW[2]	0.17		3.7% FCM	−0.15	Abdallah and McDaniel, 2000
			2×, 305-d, mature equivalent fat yield	−0.11	
			Days open	−0.11	
Birth weight	0.53		Weaning weight	0.79	Coffey et al., 2006
			Calving weight	0.50	
Weaning weight	0.45		Calving weight	0.59	
Calving weight	0.75				
Live weight[3]	0.35		Fat- and protein-corrected milk	−0.10	Lassen and Løvendahl, 2016
Live weight[4]	0.48		Milk yield	−0.06	Veerkamp et al., 2000
			Fat yield	0.31	
			Protein yield	0.20	
			DMI	0.76	
			Energy balance	0.45	
			Interval until first luteal activity	−0.11	

[1]Average BW from DIM 5, 60, 120, 180.

[2]Predicted BW after calving.

[3]Weekly average live weight measured by automatic milking systems.

[4]Live weight within the first week of first-lactation cows.